pulled off by the action of electricity. The cathode of a vacuum-tube was covered with chalk. It exhibits phosphorescence of orange-yellow colour, while in a short time the tube-wall becomes covered by a very delicate layer of chalk, without losing its clearness and transparency, and phosphoresces like chalk. Puluj believes that the yellow-coloured phosphorescence observed on metallic cathodes is caused by the phosphorescence of the oxides covering the metal.

## *GEOGRAPHICAL NOTES*

AT its annual meeting the Russian Geographical Society elected as vice-president M. Semenoff, and Baron Osten-Secken as his "aid." The great Constantine medals were awarded to M. Moushketoff, for his geological researches in Central Asia, and to M. Yanson, for his remarkable work on "Comparative Statistics of Russia," the two first volumes of which have already appeared; the Lütke gold medal was awarded to Baron Kaulbars for his papers on the Lowlands of the Amu-daria; the two great gold medals instituted last year for ethnographical and statistical researches were awarded to Dr. Pyasetzky for his work, "Travels to China during the Years 1875-77," and to M. Roussoff for his statistical description of the Nyejin district. Small gold medals were awarded to M. Nordkvist, who took part in Nordenskjöld's expedition; to M. Potanin for his travels in Mongolia; to M. Tyaghin, for meteorological observations on Novaya Zemlya, and to M. Maïnoff for anthropological explorations among the Mordovians. Silver medals were awarded to Mme. Treskina and to MM. Andrianoff, Unterberger, Polonsky, Orloff, Skassi, Karatin, Zinovieff, Krasovsky, and Mikhalenko.

WE learn from the last number of the *Izvestia* of the Russian Geographical Society that the Society sends this spring M. Polyakoff with an assistant for the exploration of Sakhalin Island. M. Polyakoff will start from Odessa, on board of a Russian ship, and proceed to Sakhalin, where he will stay during a year; thence he will go to the Mantchurian shore of the Pacific for further explorations.

THE explorer Begaert has arrived at Lisbon. He was sent by the King of the Belgians to make scientific researches on the route of Mr. Stanley at Vivi and other parts of Zaire.

WE are glad to learn that the U.S. Congress have decided to appropriate 175,000 dollars to send out an expedition in a whaling vessel in search of the missing steamer *Jeannette*, which was sent out in 1879 by Mr. Gordon-Bennett to carry on Arctic exploration by way of Behring Strait. The initiative in this matter is due to Chief-Justice Daly, President of the American Geographical Society.

IN addition to two papers descriptive of the visits of Mr. Leigh Smith to Franz-Josef Land and Mr. Delmar Morgan to Kuldja, the new number of the Geographical Society's *Proceedings* gives Mr. F. C. Selous' notes on some of his many journeys in South Central Africa, those dealt with here being to the north of the Zambesi between the 27th and 29th meridians, and in the neighbourhood of the River Chobe which empties into the great river above the Victoria Falls. We gave last week the text of the interesting note on Col. Prejevalsky, in addition to which we may refer to the record of some altitudes recently determined in Matabele Land, and a note of Dr. Otto Finsch's explorations in Polynesia. The maps this month are of the South Coast of Franz-Josef Land and the Central Zambesi region.

WE observe that M. Henri Duveyrier's interesting observations on the question of the sources of the Niger appear in the last (December) number of the French Geographical Society's *Bulletin*, but we regret to find that they are published without a map.

IN last week's issue of *Les Missions Catholiques* Mgr. Lavigerie, Archbishop of Algiers, commences an account of the missions of Equatorial Africa, with the direction of which he has been charged. There is also a letter from Père Antonin de Reschio in Brazil, in which will be found some notes on curious traditions among the Indians.

MARQUIS ANTINORI and the other members of the Italian expedition to Shoa are expected shortly at Zeila. It is also stated that Signor Libman, an Italian traveller, has gone to Assab in order to make an attempt to open commercial relations with the interior and to survey some of the little-known regions in the neighbourhood. Signor Giuletti, who accompanied the Italian official representative to Assab in January, is charged by the Italian Geographical Society to undertake a journey through the country of the Danakil and Adel tribes, and to study the best means for opening a trade-route between Assab and Abyssinia. His mission has considerable geographical importance, as the region to be traversed is unknown, and he will have an opportunity of solving the problem of the River Gualima, which probably he found to empty into some lake in the interior, as the Hanash does, if indeed it be not part of the latter river-system.

CAPT. NEVES FERREIRA, Governor of Benguela, and other Portuguese officers, have placed their services at the disposal of the Lisbon Geographical Society for a scientific expedition across Africa, to start from the West Coast.

THE *Sydney Morning Herald* of January 17 publishes a telegram from their Queensland correspondent as follows, dated January 14:—"Skuthorpe arrived two days ago from his exploring trip out west. He reports having travelled 200 miles inside the South Australian boundary, and in the Herbert River discovered relics of Leichhardt, consisting of his diary and Classen's diary; also a telescope with presentation engraving, compasses, and other things. These, he alleges, are in two packs which he has brought with him. The diary of Classen is to the effect that he left Leichhardt at the Saltwater Creek while he searched for water, and that on his returning he found the party dead, and then joined the blacks, with whom he lived until three years ago. Skuthorpe will not allow any one to inspect the alleged relics, and here it is considered doubtful whether they are genuine."

INTELLIGENCE has been received at the Foreign Office from Her Majesty's Consul at Mozambique, which confirms the report of the deaths of Capt. Phipson-Wybrants and Messrs. Carr and Mears, of the Wybrants' expedition. Mr. Mayes is stated to be at Umzeilas, and Mr. Owen to have left with the remainder for Inhambane, whither Her Majesty's ship *Ruby* will proceed forthwith.

## *ON THE VISCOSITY OF GASES AT HIGH EXHAUSTIONS*[1]

II.

*INFLUENCE of Aqueous Vapour on the Viscosity of Air.*—In the foregoing experiments many discrepancies were traced to the presence of moisture in the gas. The influence of aqueous vapour does not appear to be great when present in moderate amount in gas of normal density, but at high exhaustions it introduces errors which interfere with the uniformity of the results. A series of experiments were accordingly undertaken to trace the special action of aqueous vapour when mixed with air.

Up to a pressure of about 350 millims. the presence of aqueous vapour has little or no influence on the viscosity of air. The two curves are in fact superimposed. At this point, however, divergence commences, and the curve rapidly bends over, the viscosity falling from 0·0903 to 0·0500 between 50 and 7 millims. pressure. Here it joins the hydrogen curve, and between 7 millims. and 1 millim. they appear to be identical.

These results are partly to be explained by the peculiar action of water vapour in the apparatus. At the normal pressure the amount of aqueous vapour present in the air, supposing it to be saturated, is only about thirteen parts in a million, and the identity of the log dec. with that of dry air shows that this small quantity of water has no appreciable action on the viscosity. When the pump is set to work the air is gradually removed, whilst the aqueous vapour is kept supplied from the reservoir of liquid. As the exhaustion approaches the tension of aqueous vapour, evaporation goes on at a greater rate, and the vapour displaces the air with increasing rapidity; until, after the pressure of 12·7 millims. is passed, the aqueous vapour acts as a gas, and, being constantly supplied from the reservoir of water (as long as it lasts), washes out all the air from the apparatus, the log dec. rapidly sinking to that of pure water gas.

This explanation requires that the viscosity of pure aqueous vapour should be the same as that of hydrogen, at all events between 7 millims. and 1 millim. pressure. The facts can, however, be explained in another way. During the action of the Sprengel pump sufficient electricity is sometimes generated to render the fall tubes luminous in the dark. It is conceivable

[1] Abstract of a paper read before the Royal Society, February 17, 1881, by William Crookes, F.R.S. Continued from p. 423.

that under such electrical influence the falling mercury may be able to decompose aqueous vapour at these high exhaustions, with formation of oxide of mercury and liberation of hydrogen. Of these two theories the latter appears to be the more probable.

The presence of water vapour shows itself likewise in the very slight amount of repulsion produced by radiation. Repulsion commences in air at a pressure of 12 millims., whilst at a higher exhaustion the maximum effect rises to over 40 divisions. Here, however, repulsion does not begin till the exhaustion is higher than the barometer gauge will indicate, whilst the maximum action after long-continued pumping is only 9 divisions.

*Viscosity of Kerosoline Vapour.*—The rapid diminution of viscosity in the last experiment after reaching the pressure of 400 millims., is probably due to the aqueous vapour in the air being near its liquefying point. It was thought advisable to test this hypothesis by employing a somewhat less easily condensible vapour, which could be introduced into the apparatus without any admixture of air. An experiment was accordingly tried with a very volatile hydrocarbon, commercially known as Kerosoline, boiling at a little above the ordinary temperature. The vapour of this body was introduced into the well-exhausted apparatus, when the gauge at once sank 82·5 millims. After the usual precautions to eliminate air a series of observations were taken.

The loss of viscosity is more rapid than with any other gas examined except aqueous vapour. Conversely a very great increase of viscosity occurs on increasing the pressure from 8 to 82·5 millims. The explanation of this is that the vapour of kerosoline is very near its liquefying point, and therefore very far from the state of a "perfect" gas.

The negative bend in the curve at about 10 millims. pressure, already noticed with other gases, is strongly marked with this hydrocarbon vapour.

*Discussion of Results.*—When discussing the viscosity results obtained with the different gases experimented with, the author gives the following approximate comparison of viscosities, such as is afforded by a comparison of the log decs. of each gas and that of air, comparing the ratio with that obtained by Graham, Kundt and Warburg, and Maxwell.

| | Graham. | Kundt & Warburg. | Maxwell. | Crookes. |
|---|---|---|---|---|
| Air ... ... ... ... | 1·0000 | 1·0000 | 1·0000 | 1·0000 |
| Oxygen ... ... ... | 1·1099 | — | — | 1·1185 |
| Nitrogen ... ... ... | 0·971 | — | — | 0·9715 |
| Carbonic oxide... ... | 0·971 | — | — | 0·9715 |
| Carbonic anhydride .. | 0·807 | 0·806 | 0·859 | 0·9201 |
| Hydrogen... ... ... | 0·4855 | 0·488 | 0·5156 | 0·4439 |

Graham's numbers are the theoretical results deduced from his experiments on transpiration of gases. They are, he says,[1] the numbers to which the transpiration times of the gases approximate, and in which they have their limit. Graham concludes that the "times of oxygen, nitrogen, carbonic oxide, and air are directly as their densities, or equal *weights* of these gases pass in equal times. Hydrogen passes in half the time of nitrogen, or twice as rapidly for equal volumes. The result for carbonic acid appears at first anomalous. It is that the transpiration time of this gas is inversely proportional to its density when compared with oxygen."

The proportion between air and oxygen, nitrogen, or carbonic oxide is not very different at any degree of exhaustion to that which it is at 760 millims. Carbonic anhydride, however, is different; the proportion between it and air holds good between 760 and 650 millims. Then it gets lower and lower as the pressure sinks, until 50 or 55 millims is reached, when the proportion between it and air again becomes constant.

Hydrogen, however, is entirely different to the other gases; its log dec remains the same to a very high exhaustion, and, that of other gases sinking, it is evident that the proportion between this gas and any other is different for each pressure.

It must not be forgotten that the pressure of 760 millims. is not one of the constants of Nature, but is a purely arbitrary one, selected for our own convenience when working near the level of the sea. In the diagrams accompanying his R.S. paper the author has started from this pressure of 760 millims., and has given the log dec. curves which approximately represent the viscosities through a wide range of exhaustion. But the curves might also be continued, working downwards instead of upwards. From the shape and direction in which they cut the 760 line, it is reasonable to infer their further progress downwards, and we may assume that an easily liquefiable gas will show a more rapid increase in viscosity than one which is difficult to liquefy by pressure. For instance, hydrogen, the least condensible of all gases, shows scarcely any tendency to increase in log dec by pressure. Oxygen and nitrogen, which are only a little less difficult to condense than hydrogen, show a slight increase in log dec. Carbonic anhydride, which liquefies at a pressure of 56 atmospheres at 15° C., increases so rapidly in log dec. that at this pressure it would have a log dec. of about 1·3, representing an amount of resistance to motion that it is difficult to conceive anything of the nature of gas being capable of exerting.

Kerosoline vapour is rendered liquid by pressure much more readily than carbonic anhydride. Its curve shows a great increase in density for a very slight access of pressure.

Again, aqueous vapour is condensible to the liquid form with the greatest readiness; and the almost horizontal direction of the curve representing aqueous vapour mixed with air carries out the hypothesis.

It follows, then, that Maxwell's law holds good for perfect gases. The disturbing influence spoken of in the commencement of this paper as occasioning a variation from Maxwell's law, is the tendency to liquefaction, which prevents us from speaking of any gas as "perfect," and which hinders it from obeying Boyle and Mariotte's law. The nearer a gas obeys this law the more closely does it conform to Maxwell's law.

Maxwell's law was discovered as the consequence of a mathematical theory. It presupposes the existence of gas in a "perfect" state—a state practically unknown to physicists, although hydrogen gas very nearly approaches that state. An ordinary gas may be said to be bounded, as regards its physical state, on the one side by the sub-gaseous or liquid condition, and on the other side by the ultra-gaseous condition. A gas assumes the former state when condensed by pressure or cold, and it changes to the latter state when highly rarefied. Before actually assuming either of these states there is a kind of foreshadowing of change, with partial loss of gaseity. When the molecules, by pressure or cold, are made to approach each other more closely, they begin to enter the sphere of each other's attraction, and therefore the amount of pressure or cold necessary to produce a certain density is less than the theoretical amount by the internal attraction exerted on each other by the molecules. The nearer the gas approaches the point of liquefaction the greater is the attraction of one molecule to another, and the amount of pressure required to produce any given density will be proportionally less than that theoretically required by a "perfect" gas.

A noteworthy point in connection with the elasticity of glass is observed on the curves of viscosity. They are not continued beyond the 0·02 M exhaustion, but the general form of the curves indicates that, if they were produced beyond the limits of the observations, they would cut the line representing the absolute vacuum. The curve representing the repulsion accompanying radiation evidently goes up to the zero point, showing that at an absolute vacuum there would be no repulsion. The curves of viscosity cannot, however, be supposed to end at the zero point without a sudden change in direction. They evidently touch the top line of zero pressure long before the log dec. of 0·00 is reached. This means that in an absolute vacuum there would still be a measurable amount of viscosity. This is probably due to the viscosity of the glass torsion fibre, for it has been ascertained that glass is not perfectly elastic, but will take a permanent *set* if kept under constraint for a considerable time.

The author gives an instance which has come under his own notice. In 1862 he purchased a piece of glass lace, and some spun glass from which the lace was made. The spun glass is in long straight threads, about 0·001 inch diameter, and has occasionally been used for torsion fibres. The fibres of which the lace was made were originally straight, but the twists and bends in which they have been kept for eighteen years have permanently altered their direction, and on dissecting a portion of the lace the component fibres remain distorted and bent, even when free to resume their original shape.

Were glass perfectly elastic the log dec in an absolute vacuum would probably be equal to *zero*: there would then be no diminution in the arc of vibration, and the torsion fibre once set swinging would go on for ever.

*The Ultra-Gaseous State of Matter.*—A consideration of the curves of viscosity of the gases, especially hydrogen, which are

[1] *Loc. cit.* pp. 178, 179.

given in the foregoing pages, confirms the supposition that a gas, as the exhaustions become extreme, gradually loses its gaseous characteristics, and passes to what the author has ventured to call an ultra-gaseous state. Certainly it ceases to possess many of the properties usually held to be the essential attributes of gaseity.

For instance, Maxwell's law that the viscosity of a gas is independent of pressure holds good to a certain point, and then it rapidly breaks down. All gases appear to obey Maxwell's law between some limits of exhaustion, and diverge from it at others. Thus the nearly perfect gas hydrogen shows signs of increasing in viscosity as the pressure approaches 760 millims., and it is very improbable that its viscosity would remain the same if the pressure were to be considerably increased. Between 5 and 35 millims. the respective viscosities of carbonic anhydride, carbonic oxide, nitrogen, oxygen, and air scarcely vary at all, showing that between these limits they are practically as "perfect" gases as hydrogen is throughout the whole barometric range from 760 millims. to 1 millim., and here therefore they obey Maxwell's law as perfectly as hydrogen does. The change to the ultra-gaseous state commences to be assumed at about an exhaustion of half a millim. In hydrogen the change then proceeds slowly, but in the less perfect gases experimented with, the change to ultra-gas takes place with greater rapidity.

In gases, variation of pressure in different parts of a closed vessel equalises itself with great rapidity, but in the ultra-gaseous state differences of pressure may exist for twenty minutes or more in different parts of the apparatus.

In gases, electrically charged bodies do not permanently retain their charge, but gradually discharge themselves. In ultra-gas, however, a pair of electrified gold leaves have remained repelled at absolutely the same angle for thirteen months.[1]

Another property of gases is that of facilitating the cooling of bodies immersed in them, by communicating an increase of motion to the molecules of the gas which carry it to the walls of the containing vessel,—*i.e.* by *carriage* instead of *convection*. There is little difference in the rate of cooling with increased exhaustion, so long as we work with such ordinary good vacua as can be obtained by air-pumps. For if, on the one hand, there are fewer molecules impinging on the warm body (which is averse to the carriage of heat), yet, on the other hand, the mean length of path between collisions is increased so that the augmented motion is carried farther; the number of steps by which the temperature passes from the warmer to the cooler body is diminished, but the value of each step is correspondingly increased. Hence the difference of velocity before and after impact may make up for the diminution in the number of molecules impinging.

In gases, therefore, the rate of cooling is little affected by rarefaction, the law in this case being analogous to that governing the viscosity.

In a paper which the author has recently read before the Royal Society,[2] he shows that when the exhaustion is carried to so high a point that the mean free path is comparable with the diameter of the containing vessel, the rate at which heat is conveyed across is much diminished. The molecules are now in the ultra-gaseous state, and further exhaustion produces a notable fall in the rate of cooling, an increase of exhaustion from 20 M to 2 M retarding the carriage of heat more than all the previous exhaustion from 760 millims. to 20 M.

The author has shown elsewhere[3] that the property of gaseity is pre-eminently a property dependent on collisions. A given space full of air at the ordinary pressure contains millions of millions of molecules rapidly moving in all directions, each molecule momentarily encountering millions of other molecules in a second. In such a case the length of the mean free path of the molecules is exceedingly small compared with the dimensions of the containing vessel, and those properties are observed which constitute the ordinary gaseous state of matter—properties which depend upon constant collisions.

The gaseous state continues so long as the collisions are almost infinite in number, and of inconceivable irregularity. But in such high vacua as are now described the free path of the molecules is made so long that the hits in a given time may be disregarded in comparison to the misses, and the average molecule is allowed to obey its own motions or laws without interference; and when the mean free path is comparable to the dimensions of the containing vessel, the properties which constitute gaseity are reduced to a minimum, and the matter then becomes exalted to an ultra-gaseous state.

In the ultra-gaseous state properties of matter which exist even in the gaseous state are shown *directly*, whereas in the state of gas they are only shown *indirectly*, by viscosity and so forth.

The ordinary laws of gases are a simplification of the effects arising from the properties of matter in the ultra-gaseous state; such a simplification is only permissible when the mean length of path is small compared with the dimensions of the vessel. For the sake of simplicity we make abstraction of the individual molecules, and feign to our imagination *continuous* matter of which the fundamental properties—such as pressure varying as the density, and so forth—are ascertained by experiment. A gas is nothing more than an assemblage of molecules contemplated from a simplified point of view. When we deal with phenomena in which we are obliged to individually contemplate molecules, we must not speak of the assemblage as *gas*.

An objection has been raised touching the existence of ultra-gaseous matter in highly-exhausted electrical tubes, that the special phenomena of radiation and phosphorescence which the author has considered characteristic of this form of matter can be made to occur at much lower pressures than that which exhibits the maximum effects. For the sake of argument let us assume that the state of ultra-gas with its associated phenomena is at the maximum at a millionth of an atmosphere. Here the mean free path is about 4 inches long, sufficient to strike across the exhausted tube. But it has been shown by many experimentalists that at exhaustions so low that the contents of the tube are certainly not in the ultra-gaseous state, the phenomena of phosphorescence can be observed. This circumstance had not escaped the author's notice. In his first paper on the "Illumination of Lines of Molecular Pressure and the Trajectory of Molecules"[1] the author drew attention to the fact that a molecular ray producing green phosphorescence can be projected 102 millimetres from the negative pole when the pressure is as high as 0·324 millim. or 427 M. In this case the mean free path of the molecules is 0·23 millim.; and it is not surprising that with more powerful induction discharges, and with special appliances for exalting the faint action to be detected, the above-named phenomena can be produced at still higher pressures.

It must be remembered that we know nothing of the *absolute* length of the free path or the *absolute* velocity of a molecule; these may vary almost from zero to infinity. We must limit ourselves to the *mean* free path and the *mean* velocity, and all that these experiments show is that a few molecules can travel more than a hundred times the *mean* free path, and with perhaps a corresponding increase over the *mean* velocity, before they are stopped by collisions. With weak electrical power the special phosphorogenic action of these few molecules is too faint to be noticed; but by intensifying the discharge the action of the molecules can be so increased as to render their presence visible. It is also probable that the absolute velocity of the molecules is increased so as to make the mean velocity with which they leave the negative pole greater than that of ordinary gaseous molecules. This being the case, they will not easily be stopped or deflected by collisions, but will drive through obstacles and so travel to a greater distance.

If this view is correct, it does not follow that gas and ultra gas can co-exist in the same vessel. All that can be legitimately inferred is, that the two states insensibly merge one into the other, so that at an intermediate point we can by appropriate means exalt either the phenomena due to gas or to ultra gas. The same thing occurs between the states of solid and liquid and liquid and gas. Tresca's experiments on the flow of solids prove that lead and even iron, at the common temperature, possess properties which strictly appertain to liquids, whilst Andrews has shown that liquid and gas may be made to merge gradually one into the other, so that at an intermediate point the substance partakes of the properties of both states.

*Note on the Reduction of Mr. Crookes's Experiments on the Decrement of the Arc of Vibration of a Mica Plate oscillating within a Bulb containing more or less Rarefied Gas*[2]

THE determination of the motion of the gas within the bulb, which would theoretically lead to a determination of the coefficient of viscosity of the gas, forms a mathematical problem

[1] *Proceedings* of the R. S., No. 193, 1879, p. 347.
[2] *Proc.* R. S., No. 208, 1880, p. 239.
[3] *Proc.* R. S., No. 205, 1880, p. 469.

[1] *Phil. Trans.* part 1, 1879, the Bakerian Lecture.
[2] Abstract of a paper read before the Royal Society, February 17, by Prof. G. G. Stokes, Sec.R.S.

of hopeless difficulty. Nevertheless we are able, by attending to the condition of similarity of the motion in different cases, to compare the viscosities of the different gases for as many groups of corresponding pressures as we please. Setting aside certain minute corrections which would have vanished altogether had the moment of inertia of the vibrating body been sufficient to make the time of vibration sensibly independent of the gas, as was approximately the case, the condition of similarity is that the densities shall be as the log decrements of the arc of vibration, and the conclusion from theory is that when that condition is satisfied, then the viscosities are in the same ratio. Pressures which satisfy the condition of similarity are said to "correspond."

It was found that on omitting the high exhaustions, the experiments led to the following law:—

The ratios of the viscosities of the different gases are the same for any two groups of corresponding pressures. In other words, if the ratios of the viscosities of a set of gases are found (they are given by the ratios of the log decrements) for one set of corresponding pressures, these pressures may be changed in any given ratio without disturbing the ratios of the viscosities.

This law follows of course at once from Maxwell's law, according to which the viscosity of a gas is independent of the pressure. It does not however by itself alone prove Maxwell's law, and might be satisfied even were Maxwell's law not true. The constancy however of the log decrement, when the circumstances are such that the molar inertia of the gas may presumably be neglected, proves that at any rate when the density is not too great that law is true; and the variability of the log decrement at the higher pressures in all but the very light gas hydrogen is in no way opposed to it, though Mr. Crookes's experiments do not enable us to test it directly, but merely establish a more general law, which embraces Maxwell's as a particular case.

The viscosities referred to air as unity which came out from Mr. Crookes's experiments were as follows:—

| | |
|---|---|
| Oxygen | 1·117 |
| Nitrogen and carbonic oxide | 0·970 |
| Carbonic anhydride | 0·823 |
| Hydrogen | 0·500 |

The viscosity of kerosoline vapour could not be accurately deduced from the experiments, as the substance is a mixture, and the vapour-density therefore unknown. Assuming the relative viscosity to be 0·0380, the vapour-density required to make the experiments fit came out 3·408 referred to air, or 49·16 referred to hydrogen.

When once the density is sufficiently small, the log decrement may be taken as a measure of the viscosity. Mr. Crookes's tables show how completely Maxwell's law breaks down at the high exhaustions, as Maxwell himself foresaw must be the case. Not only so, but if we take pressures at those high exhaustions which are in the same ratios as "corresponding" pressures, the log decrements in the different gases are by no means in the ratios of the densities.

It would appear as if the mechanical properties of a gas at ordinary pressures and up to extreme exhaustions (setting aside the minute deviations from Boyle's law, &c.) were completely defined by two constants, suppose the density at a given pressure and the coefficient of viscosity; but that specific differences come in at the high exhaustions at which the phenomena of "ultra-gas" begin to appear; and that to include these, an additional constant, or perhaps more than one, requires to be known.

## ANIMAL REMAINS IN THE SCHIPKA CAVERN

On December 6, 1880, Prof. Schaaffhausen gave a lecture to the Lower Rhine Society in Bonn, on the discoveries made by Prof. Maschke in the Schipka Cavern, near Stramberg, in Moravia. In this cavern were found remains of Bos, Ursus, Elephas, Rhinoceros, Leo, and Hyæna, besides roughly-hewn implements of quartzite, basalt, and flint, and some incisor teeth of Ursus, which were cut into on both sides at the beginning of the crown, perhaps because people did not yet know how to bore a hole into the root. Carbonised animal bones in numerous small fragments were met with. A solitary human relic was found in a protected place at the wall of a side passage of the cavern, and near a fireplace. It was the fragment of a lower jaw, amid ashes and inter-breccia of lime. The same layer contained mammoth remains and stone implements. Of the jaw only the front part with incisors, one canine, and the two premolars, of the right side remained. The latter three teeth were still in the jaw undeveloped, but were visible, because the front wall of the jaw was wanting. The largeness and thickness of the jaw, first of all, were remarkable. The teeth-development corresponds to the first year of life, but the jaw and the teeth are as large as those of an adult. As is the rule with man, the first pre-molar seemed nearest being cut; next to it came the canine, then the second pre-molar.

The height of the jaw in the line of symphysis measures, to the alveolar border, 30 mm., to the end of the incisors 39 mm. (In the jaw of a child seven years old the corresponding measurements were 23 mm. and 30 mm.; in a girl nine years old 24 mm. and 33 mm.; in a boy of 12, 22 mm. and 31 mm. The jaws of eight adults measured in height, to the alveolar border, on an average, 31 mm.) The jaw fragment, at its lower border, in the line of symphysis, is 14 mm. thick; under the canine tooth the thickness is 15 mm. (In an ordinary adult jaw the thickness in the line of symphysis is about 11 mm.) Now when the cutting surface of the incisors is placed horizontally, the under part of the prognathous jaw bends so much back that one misses the chin as a prominence. A vertical from the front alveolar border falls 4 to 5 mm. in front of the lower border of the jaw. The hinder surface of the symphysis is placed obliquely, as occurs in a high degree in the anthropoids, and in lower degree in savage races, but has also before been observed in fossil human remains, as in the jaw of La Naulette, to which this jaw from the Schipka Cavern has much similarity. The form of the incisors is adapted to the thick prognathous jaw; the broadest part of the root measures from front to back 8¼ mm., whereas the ordinary measurement here is 6 mm. Further the teeth are bent convex in front. The curvature corresponds to a radius of 27 mm. The *spina mentalis interna* is absent, and instead there is, as in the anthropoids, a cavity, at the lower border of which some unevenness can easily be felt. The prominences for attachment of the *Musculi digastrici* are well marked, implying a correspondingly strong development of the antagonistic muscles, the masticatory. All these features were also met with on the jaw of La Naulette, but more developed. It is probable that the jaw of the Schipka Cavern also had the pithecoid peculiarity, that its tooth-line was not horizontal, but rose from the premolars to the incisors, and its body was higher in front than at the sides, because the cutting-surface of the outer incisors sinks obliquely outwards. The size of the canine tooth is remarkable, its enamel crown being 13·5 mm. long. (In the fossil lower jaw of Uelde the canine tooth exceeds the premolars about 3·5 mm. According to measurement on ten European adult skulls with the teeth hardly, or not at all, worn down, the crown of the canine tooth was 11·5 mm. long. Only once, among more than fifty skulls, was it found 14 mm.) It cannot well be supposed that this jaw, caught in dentition, belonged to an individual of giant growth, since in such individuals the excessive growth, according to Langer, first begins about nine to ten years of age. The assumption that some pathological cause had hindered the development of the three teeth that remained within the jaw seems quite groundless. As little can we suppose that in the prehistoric time the teeth development was retarded, and that the change of teeth occurred at a later age, since a quicker development corresponds to a lower organisation. (All mammals come into the world with teeth, and the orang changes its teeth sooner than man.)

The size of the front part of the jaw however may in itself be regarded as pithecoid; and there is more reason for this in that other pithecoid characters are present. The aspect of the grey-yellow bone with small dark branching spots on it is met with often in cavern bones. The enamel of the teeth is quite like that of the Quaternary cave animals; it shows longitudinal fissures with dark infiltration; while near these appear bluish, and in some places yellow, spots.

## SOME REMARKS ON PERIPATUS EDWARDSII, BLANCH.

Since I learnt from Mr. Moseley's notes on the species of *Peripatus* (*Ann. and Mag. of Nat. Hist.*, v. ser., iii., 263), that one of them, referred by Grube to *P. Edwardsii*, had been obtained from this country, in the neighbourhood of Colony Tovar[1]), I tried to get specimens of this highly interesting

[1] Not Colony *Jowar*, as the name is printed in Mr. Moseley's paper.